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Fluids and Combustion Facility Document

Fluids and Combustion Facility (FCF)/Combustion Integrated Rack (CIR) Critical Design Review (CDR) Board Report

Date: July 1, 2002

Approved by William E. Taylor, Chairman, FCF/CIR CDR Review Board

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1.0 INTRODUCTION

The Fluids and Combustion Facility (FCF) Combustion Integrated Rack (CIR) Critical Design Review (CDR) was held May 28 to 31, 2002 at the Ohio Aerospace Institute (OAI). The review was performed in a presentation mode, with presentations on various appropriate topics being given by members of the NASA Glenn Research Center (GRC) Project Office, and the Microgravity Research, Development, and Operations Contract (MRDOC) contractor and their sub-contractors. Preceding the review was an intensive period of documentation review and discussion by members of the NASA community, including NASA Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), and of course the GRC. Various members of the Science Team also participated in these reviews.

Members of the Review Board were:

William Taylor, Chairman	Retired NASA/MSFC
Mun Young Choi	Drexel University/Combustion Science
Kenneth Adams	GRC/Safety and Mission Assurance
Robert Corban	GRC/FCF Project
Daniel Gauntner	GRC/Systems Engineering
John Taylor	GRC/Engineering
Michael Miller	JSC/ISS Technical
Janet Kavandi	JSC/Crew & Human Factors
Ricky Cissom	MSFC/Operations & Integration
Tim Smith	MSFC/Engineering

The Review Board findings are summarized in Section 2.0 - Executive Summary. Details of the findings are in Section 3.0 - Review Team Report. Caution is urged should only the Executive Summary be read, since many factors used to arrive at this summary are not included with it.

The Review Board wishes to recognize and acknowledge the efforts of all who helped make the review a success. Presenters were invariably knowledgeable, open, professional and courteous in responding to questions and comments from the Team and others. Support personnel significantly helped the meeting go smoothly and efficiently. All who participated and/or supported are to be commended.

2.0 EXECUTIVE SUMMARY

A generalized statement of the rationale for a Critical Design Review (CDR) is to assess a project at the 90-95% design complete stage, for assuring readiness to proceed into the manufacturing/procurement phase. The Review Board was also asked to assess the programmatic aspects of the Project, considering the current Project management structure, past performance and plans as reflected by Engineering Change Proposal 2 (ECP-2), submitted recently by the MRDOC contractor, Northrop Grumman Information Technology (NGIT).

The Board felt that the Project had made significant progress since the Preliminary Design Review (PDR). It was especially evident that the contractor recognized the need to achieve the science requirements of the Project, and had expended significant effort in this area. They had also worked diligently with JSC/International Space Station (ISS) personnel to understand and comply with ISS requirements, including Flight Crew and Human Factors requirements.

The NASA/GRC Project Office recognized at the out-set, that the Project was not at the 90-95% design completion state, with shortfalls in flight drawing completions, specifications and requirements requiring significant work to achieve satisfactory status, numerous open items such as analyses, requirements flow-down, testing on engineering models etc. yet to be completed. The assessment of the Review Board was therefore based on the known status including these shortfalls. The Review Board's finding was that the Project is not in position to proceed without significant additional effort. While proceeding on a piecemeal/high priority basis on long lead items can be done, it will incur potentially significant risks due to the lack of an integrated and validated design.

Programmatically, the Project appears to have recognized the problems that exist due in large part to the current MRDOC contract structure, and through ECP-2 is attempting to correct these problems. Without being privy to all the details of ECP-2, it would appear that the Project is on the right path to correcting past weaknesses. The Board stresses that the proposed new Work Breakdown Structure (WBS) and Organization appears to separate Design and Development from Integration and Operations, and that often in the past we have seen that such divisions lead to difficult and inefficient integration and operations activities. The Board believes that a significant amount of effort will be required to properly structure the project based on ECP-2, and that proceeding to design completion in parallel will be very challenging.

Finally, the "zero slack" schedule posture presented by NGIT in ECP-2 must be considered unacceptable. This is compounded by the tight funding posture of the Project; a dilemma of significant proportions. Again, a solution to this situation should be developed expeditiously.

3.0 REVIEW BOARD REPORT

The following report is structured closely, if not identically, to the Review Board Charter contained in GRC memo 6700 (51-02), subject: Appointment of Review Board for the Critical Design Review of the Fluids and Combustion Facility Combustion Integrated Rack. Each of the major topics were evaluated by the full Board, and the report attempts to integrate and synthesize the often diverse inputs into a cohesive report content. Clearly this is not always possible, and where extremely different opinions were existent, the Chairman exercised his prerogative in attempting to establish the Board's position. Where requested, a minority position is included in the Report. The report follows a format of restating the Charter criteria item, numbered from one to twelve for convenience of referencing, followed by Board findings including strengths and weaknesses, recommendations, Requests For Action (RFA) (Appendix C), and Review Item Discrepancies (RID) identified, (Appendix D). RFAs do not cover all recommendations cited in this report. The FCF Project may elect to transition Recommendations to Actions if appropriate. Please note that there has been minor restructuring of one Charter item, i.e. "Evaluate the prime Contractor's fabrication/acquisition plans and readiness to construct the CIR (and FCF common hardware items)," into two parts. The first element of this criterion was merged with other Programmatic items as part of Criteria 10; the second part became a new Criteria item 12, since the Board felt it warranted special attention.

1. Establish that the CIR and FCF common hardware designs accommodate the science requirements. Evaluate the capabilities of the CIR to accommodate the initial payloads that are planned to fly in it, i.e., the Multi-User Droplet Combustion Apparatus (MDCA), the Flow Enclosure Accommodating Novel Investigations in Combustion of Solids (FEANICS) and the Multi-User Gaseous Fuel Apparatus (MGFA).

The contractor, at the designer level, seems to have a good working knowledge of Combustion Science requirements. The current CIR design with the common hardware designs seems to meet most science requirements but complete determination of science compliance cannot be ascertained due to incomplete Science Requirements Envelope Document (SRED) requirements flow-down and testing. The biggest concern in meeting science requirements may occur with the Fluids Integrated Rack (FIR) since the contractor has not shown compliance to a common set of CIR/FIR requirements especially in the Air Thermal Control Unit (ATCU) development. The contractor indicates the ATCU does not comply and will determine in the future the degree of noncompliance. This approach to design indicates that the ATCU will not be common (increased costs) or the FIR must "live with the CIR oriented design."

Recommendation 1: Indicate which requirements are "Will Comply" and perform compliance testing. Complete assessment/testing of ATCU to assure common design is "Common".

Recommendation 2: Institute/continue a process to involve the Principal Investigators (PI) and Project Scientists (PS) in design evaluations and decisions, to ensure effective and efficient design solutions.

It appears that the program has made significant progress toward meeting the requirements for the MDCA and the FEANICS. Much progress has also been made to meet the requirements of the MGFA, but the issue of reverse flow has not been approved by Safety. A STRENGTH is the number of data points that will be enabled by the design. A minor WEAKNESS may the ability to process all the data downloads in sufficient time to impact following data points.

For the MDCA, the shortfall assessment at this stage relates to the simultaneous attainment of field of view and framing rate and the depth of field. The measurement of droplet diameter is at the heart of all of the planned MDCA experiments. In the FEANICS experiments, the critical noncompliance is related to the power for the heating and ignition of the solid fuel. In the MGFA experiments, the major noncompliance is related to the flow control of oxygen gas (O_2) into a fuel/inert environment. The issue is

to provide necessary duration of flow to complete the requirements are currently beyond that provided by the valve timer.

PI interface compliance is documented for the MDCA only. 56 of 96 science-related items in CIR B-specification are not met, some of which are significant.

Recommendation 3: Develop a formal process involving all parties for reaching closure on B-specification issues. Increase the attention to downstream payload accommodations such as FEANICS. Perform a review and update CIR requirements compliance statements to reflect the total scope of requirements. (Reference RFA No. 7).

2. Establish that the CIR and FCF common hardware detailed designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved.

It would appear that at the B-specification level, the design does satisfy most requirements. This is based on the completeness and fidelity of completed Engineering model hardware packaging and testing and other analysis/verification information. However, satisfaction of design-to requirements is essentially based on 1) a flow-down of requirements; 2) definition of appropriate specifications and verifications; and 3) validation of the resultant design through the verification process. Based on this approach, the FCF CIR cannot be judged as meeting design-to requirements. This is because a) B-specifications are not approved and "flowed-down; b) C-specifications are not completed and approved; and c) validation of analyses are not completed since many are lacking and final design drawings are missing and/or incomplete.

Specifically, several key feasibility issues remain, namely: the Serial Data Link (SDL) (have not demonstrated a robust end-to-end signal link from cameras across fiber optics to data acquisition hardware) and Object Tracking Performance (Common-Image Processing Storage Unit (C-IPSU) does not match the capability of the Image Processor Package (IPP) at tracking objects at higher speeds) and mechanical packaging of the IPP (have not demonstrated that they can fit in the allocated footprint on the optics bench). There is a tough requirements conflict between thermal air cooling and acoustic noise. Air leakage around Optics Bench and connections was not taken into account in thermal analyses and will reduce already thin thermal margins on several components. (Reference RFA No. 1). Key diagnostics Engineering Model (EM) packages have not been demonstrated, including IPP, SDL, High Frame Rate (HFR)/High Resolution (HR), and High Bit Depth/Multi-spectral (HiBMs).

Recommendation 4: Address RFA on Acoustic Noise; continue ongoing development tests of SDL and C-IPSU. Update the thermal analyses to address air leakage and employ design modifications where needed. Complete the assessment on the need for the IPP.

The contractor at the CDR meeting identified numerous "exceptions." The Board was left with the impression that until the question came up, the contractor had no definitive list of exceptions, and therefore did not understand the magnitude of the problem. The general impression was that the contractor expected these to be agreed to by the ISS Program; the Board's feeling is that this could well be an erroneous expectation. While many have little technical risk, they are none-the-less impacts to design and testing. It is especially troublesome considering the time it takes in the "submittal" process, and the time it takes to get resolution. Making an assumption that the ISS Program will accept these, and finding out later that they will not, places the design at significant risk.

Recommendation 5: Develop a plan (who, what, when, etc.,) for resolving exceptions including waiver submittals. Assure that noncompliance areas requesting exceptions will not severely limit on-orbit utilization. (Reference RFA No. 8).

3. Review the results of CIR and FCF common hardware engineering model system and package tests, and establish that any impacts on the flight or end item hardware specifications or designs have been addressed.

A significant amount of progress has been made through the use of hardware engineering models and package tests. High fidelity engineering models and breadboards have been tested. Several engineering models have not yet been developed and are at the breadboard stage. The most critical is the IPP for imaging and acquisition. Even for the packages that have engineering models, there are many open issues that must be addressed including the testing/calibration of the gas chromatograph for the fuels and the inert gases, illumination to provide a higher power output and a more uniform distribution. Testing impacts that may require modifications to the current design, specifications, and drawings were not clearly identified. In areas where the design was not meeting a requirement (e.g., Acoustics) or not performing as designed (e.g., air leakage), the plans for resolution were not clear with some of the presenters unsure of follow-on direction.

Recommendation 6: Complete required testing, including "systems level tests." Define the process to impact the hardware (HW) design based on testing data.

4. Evaluate hardware interface compatibility between the CIR and other FCF racks, the International Space Station (ISS), Shuttle/Multi-Purpose Logistics Module (MPLM), payload equipment to be operated in the CIR, FCF ground systems, the FCF operations control center, i.e., GRC Telescience Support Center (TSC) and other interfacing items.

While the Board was, in general, unfamiliar with FIR requirements, it was agreed that the design of CIR to FIR interfaces had been adequately addressed. This was also true of CIR to ISS/Shuttle and MPLM interfaces. The Project team seemed to be quite cognizant of these, and was working to address the appropriate requirements. Also the consideration of the total time required for on-orbit operations is a positive step. Many facilities that Payload Operations is working with do not understand the limitations of the Station and the availability of resources during the critical assembly phase. The design and requirements of the CIR address both and the development team should be recognized for excellent understanding of the requirements and a design that can be supported. The one area that seems to be questionable is the desire to launch all of the spares with the rack.

Recommendation 7: Given that the facility does not have internal stowage volume and the volume limitations that face the ISS today, the team should reconsider the appropriate phasing of the deployment of their critical spares and the impact on the station as a whole. (Reference RFA No. 9).

It should also be noted, that numerous Review Item Discrepancies (RIDs) were written indicating noncompliance with ISS requirements. These could well be only "paper issues," however they should receive appropriate attention in the closure process.

The Board's impressions as regards to use of FCF Ground Units and systems, and the Ground Control Center are significantly different. It was our feeling that the Project did not demonstrate an understanding of the ground elements of the infrastructure, and did not address many of the required interfaces nor show how they meet requirements. Many seemed to require more definition. Even conceptual information on such items as to how to get data from MSFC to the PIs, how to get data from the Ground Interface Unit (GIU) to TSC, how to archive it and make it available, etc were not addressed. This area is certainly not as mature as the flight hardware design and development, and appropriate attention needs to be paid to it, since it can impact flight hardware and software design approaches.

5. Review the predicted performance of the CIR and FCF common hardware packages, including reliability.

The availability and throughput analysis provided by the contractor were thorough and generally complete, although highly dependent on assumptions that were not validated. The availability analysis needs to incorporate ISS historical data or as a minimum some provisions for radiation effects on the electronics. (Reference RFA No. 2). It should also document fully the rationale, including driving assumptions that show the ability to meet an availability of 0.901 (Reference RFA No. 3). Also, allocation of many "ility" type requirements have not been incorporated into the package specifications and flowed to the suppliers/subcontractors. This could potentially lead to many system issues when performing integration and testing. The reliability analysis appears to follow classical analysis techniques and database inputs; no criticisms are provided.

6. Review the adequacy of the packaging of all CIR packages/subsystems and FCF common hardware items within the scope of this review.

The "packaging" approach appears to be well designed and implemented. Excellent use was made of the EM unit in this regard, and the packaging considering the density of items appears excellent. Packaging accommodates equipment while maintaining access and operability. While several items remain to be resolved, including mechanical packaging issues with the IPP, and access for filter change-out, none appear significant.

7. Evaluate CIR compliance with appropriate safety and quality requirements, and ensure that safety hazard controls have been identified. Evaluate the prime Contractor's fabrication/acquisition plans and readiness to construct the CIR (and FCF common hardware items).

In general, Safety and Quality requirements appear to be adequate, and appropriate implementation processes are in place. An exception to this statement would be the observation that the Contractor needs to assure flow-down of quality requirements to sub-contractors, and assure these are properly implemented. There was also concern with the Problem Reporting And Corrective Action (PRACA) system, and its lack of focus on trends that were the result of Pareto analyses via a structured review approach. An RFA was generated documenting the need to establish a (hopefully integrated) Problem Review Board that meets periodically to review current problems, evaluates trends, and takes appropriate remedial action to correct trouble spots. (Reference RFA No. 4).

The Project had recently completed the ISS Phase II Review, and had been given agreement to proceed to Phase III by the JSC Payload Safety Review Panel (PSRP). Fourteen specific JSC Form 1230 Hazard Reports were submitted; 11 agreements were reached; and 2 of 3 actions are closed. The Board considers this to be a good resultant from this review.

8. Evaluate the adequacy of the prime Contractor's approach and overarching plans for CIR and FCF common hardware qualification, verification, and test (recognizing that detailed review of verification plans/requirements will occur at a separate Verification and Test Review (V&TR).

The hardware qualification approach was discussed in portions (by box) as the review progressed. The major boxes, Electrical Power Control Unit (EPCU), Input/Output Processor (IOP) were addressed in more detail than the smaller. On other common hardware and smaller boxes, the presentation did not spell out qualification details. It was apparent, however, that the design team was cognizant of qualification requirements. Where details were available, the qualification approach appeared acceptable. In other areas, the Board was unable to ascertain specifically what the approach was to be, i.e. similarity, protoflight, full qualification unit etc.

Recommendation 8: The qualification approach for each item of flight hardware needs to be explicitly defined and justified. This should have been available for the CDR; however, should be completed as soon as possible if the Project proceeds to flight hardware build/acquisition (Reference RFA No. 10).

The Verification and Test approach was presented at a high level, perhaps appropriately considering the plan for a V&TR in the future. Weaknesses identified were in the area of integrated flight optical path testing (Reference RFA No. 5) and perhaps verification of susceptibility of flight hardware to Single Event Upset (SEU) conditions. Clearly the Dynamic Object Oriented Requirements System (DOORS) tool will be a vital part of ensuring verification requirements are satisfactorily met, and attention must be paid to getting all requirements into DOORS as soon as practical.

9. Evaluate the operability of the proposed design and compliance with applicable human factors requirements. Evaluate the adequacy of the CIR ground hardware to support operations.

Many enhancements to improve the operability of the CIR have been incorporated in the design. The contractor has made good use of the EM in this respect, using it as the tool for which it was intended, to evaluate operability (and other uses). The CIR design has taken into consideration the long-term operational ability of the hardware to minimize crew time and allow quick change-out of diagnostics. The only exception is in the placement of the air filters that requires a rotation of the bench and a somewhat difficult reach. This could become a problem if these filters need cleaning more often than anticipated. Also, the CIR setup time (including removal of the launch strut) has become excessive. This may be unavoidable, but shorter periods of time for setup must be defined to allow the crew more flexibility. While the project has worked diligently with the Crew Office to identify and overcome many Human Factors issues, several remain in the “exceptions” list, and these require early resolution.

The Board feels that significant effort remains to show how the Ground System supports the Project. Areas where the Ground Integration Unit (GIU) is not identical to the flight hardware need explicit definition quickly. Training plans for on-orbit maintenance and troubleshooting need to be developed. Effort needs to be expended on the TSC to ensure appropriate definition of tasks and definition of support displays and other capability.

The Board recognizes that the Ground System, in general, normally lags behind flight system design and definition; however there must be an integrated approach that precludes the Ground System being required to do what the flight system cannot, because of a lack of a strong systems engineering approach.

10. Assess the prime Contractor’s Project Plan, including management plan, work breakdown structure, configuration management approach, hardware/software development and test plans, schedules and costs for the prime development. Evaluate the prime Contractor’s fabrication/acquisition plans. Evaluate the technical, schedule and cost risks of the project.

The contractor’s project plan, as presented to the Board, was summarized from their ECP-2. As such it was designed to correct their perception of delinquencies in the basic contract. While the Board was not privy to the total ECP-2 submittal, it was clear that extensive changes were being proposed, not the least of which was from a “fixed price” to “cost plus” type of contract. At the level at which the Board could penetrate and evaluate the proposed change, we are in fundamental agreement as to the proposed restructuring. While the Board is not aware of all the details that require such a change, we note from the presentation material that the contractor has not performed per the schedule, has not achieved performance to their cost plan, and, as evidenced by the normal criteria for performing a CDR, has not achieved the degree of technical execution required. None of these are to be construed as critiques of the contractor’s ability to do these tasks – many factors, including support and direction by the GRC, play into these items. It is for the GRC to determine the contractor’s performance weaknesses and corrective

action plans, not the Board. Nevertheless, we have been asked to evaluate their plan, as based on ECP-2, and the following are our concerns:

- As presented, 5 of 12 key positions are not named.
- Some sub-contractor personnel were not aware whether they would still have a job after ECP-2.
- Operations and Design, Development, Test & Evaluation (DDT&E) are completely separated – something we have learned in the past leads to significant inefficiencies, and indeed lack of accountability.
- There appears to be some confusion as to chain of command.
- The "real" NGIT manager hasn't been officially named.
- The Board could not ascertain that people chosen to manage the key areas really have the talent and experience to do so. This will be an extremely difficult task to manage, if current cost/schedule/technical requirements remain as shown.

Recommendation 9: Achievement of nearly any challenging task, including this one, relies upon five elements: 1) having a sound and achievable plan; 2) having managers who have the knowledge, experience, and staff to achieve the plan; 3) having adequate resources; 4) having identified and having the ability to track progress against the plan and associated risks; and 5) having resources (reserves, slack, manpower, expertise, etc.) to mitigate these risks. The FCF CIR Project should ensure that the ECP-2 proposal satisfies these criteria before proceeding.

Configuration Management (CM), as a critical discipline of management, is of real concern. Items that were apparent to the Board include the seeming lack of CM in the presentation material (dates on charts, signatures on schedules, inconsistency between handouts and presentation material), numerous RIDs/Comments regarding drawing status, lack of "drawing check," released drawings without (required?) signatures etc. It was also not apparent that there existed a "drawing tree" or a "documentation/specification tree." The Board was also aware that this function was shown to be at risk, in a recent Safety and Mission Assurance (S&MA) evaluation by GRC. Their assessment had also identified a shortfall in staffing by the contractor. The CIR Project will be entering a crucial phase following this review. The Board considers it to be vitally important to establish and maintain configuration management and control of specifications, requirements, and drawings that will shortly be provided for baselining.

Recommendation 10: The GRC should perform an audit of the contractors configuration management and control system, identify shortcomings, and have a plan for correction before entering the flight hardware build phase. This plan should be tracked for compliance on a weekly basis until all issues are resolved, followed by reports of key metrics at monthly reviews (Reference RFA No. 11).

The Board universally viewed the area of cost and schedule as a significant problem for the Project. As presented to the Board, the ECP-2 plan has no schedule slack, and little to no "reserves." The contractor's performance in cost and schedule has clearly been unsatisfactory, and there is no clear indication to the Board that ECP-2 will change this. While changing management structure and responsibilities would appear to help the situation, the fundamental problems remain, i.e. the job is the same, the schedule is challenging, and technical difficulties have not been resolved – at CDR! A part of the contractor's solution to these items is the reorganization, as if reorganizing will solve the problem. The Board doubts that this is so. There are also identifications of risks to the plan, which imply that the contractual requirements should be changed to simplify or expedite problem resolution(s). Again, the Board is wary of changing from "tried and proven" approaches to expedited approaches under this circumstance.

Recommendation 11: Generate a sound plan. Allow the plan to establish the Flight Hardware Availability (FHA) date, with sufficient contingency to accommodate problems. Staff and cost this plan, and again establish reserve funding to cover schedule slack and any other reasonable contingencies,

e.g., increased cost of communications services. Implement this plan or de-scope the Project to allow it to be implemented on an acceptable plan.

In the area of fabrication and acquisition, other difficulties were encountered. These include:

1) Long lead items have been identified but the lead-time provided seems to be a variable. Times are different in three different areas (presentation, handout, integration plan) that indicate the times are not well defined with the vendors (Reference RFA No. 12).

Recommendation 12: Obtain commitments from the vendors for completion of hardware. Work with NASA to monitor these vendors for completing items on time.

2) The CM system is in place and approved by NASA, however the drawings have numerous problems that are attributed to CM procedures.

3) Also, upon review of the cost plan, the contractor has a minimal purchasing staff (2.5 FTEs) that goes down by 60% when acquisitions increase by 200%. This will create a significant delay in getting all the hardware purchased.

4) Lack of Product Assurance involvement with supplier.

5) 15% of drawings have produce-ability or completeness issues.

Recommendation 13: Institute drawing checkers and increase produce-ability assessment. Drawings for long-lead and critical path hardware need to be updated and completed per the CIR flight configuration.

Identification of risk, and management of risk are practiced on the Project. There is what appears to be a good Risk Management System in place and in use; however, it is only linked to the "baseline contract," and hasn't been appropriately updated to account for the realities identified by ECP-2. The risk to the Project can be evaluated by considering the three classic elements of a project, i.e. technical, schedule, and cost. Technically the contractor has failed to perform. The Project was not in position for a CDR as scheduled. Cost trends have also shown a failure to perform. Under spending the plan says, "you're not achieving what you planned," and is not a "good thing." It is also obvious that there has been a failure to meet schedule. All of these place the Project at high risk.

Recommendation 14: Following the update to the Project Plan, and definitization of ECP-2 changes, the risk list should be updated to reflect the new “challenges.” Appropriate mitigation strategy should be developed and tracked, and new risks added as they are identified (Remember, risks are a part of any project, the key is in managing them!) (Reference RFA No. 13).

11. Evaluate past review action item responses and dispositions.

The Board was made aware of the fact that there was no tracking system that could show “what happened” to PDR RIDs. This was apparently not a contractual requirement. However, RIDs are normally considered to be a “Quality Record” under ISO 9001, and whether or not the contractor tracked them is a “contractual matter.” The fact remains that they should be tracked for appropriate closure (Reference RFA No. 6).

Recommendation 15: Ensure for this review and subsequent that RIDs and other appropriate concerns are documented, tracked, and closed in an appropriate manner (Reference RFA No. 14).

The Board was provided a package of RFAs, including final dispositions. While it was encouraging to see that these were done completely, and apparently with the agreement of the initiator, it was discouraging

to see that they had only (finally) been approved by the Project just prior to the CDR. This would indicate that the tracking and closure of these items is not considered a high priority – a position that the Board strongly disagrees with.

12. "...readiness to construct the CIR (and FCF common hardware items)."

While it is clear that the Project has made significant progress since the PDR, as iterated by Board members who participated in that review, it is also obvious that the Project is not in position to begin construction/acquisition of hardware for the CIR or FCF common hardware without significant risk. The Project faces the dilemma of needing to initiate long lead item builds and/or acquisition, to have any hope of meeting required FHA dates. However these items are probably most in need of further DDT&E efforts. It was recognized and accepted by the Project at the outset of the CDR that key items had not been completed or were recognized as deficient; the CDR process has identified other shortcomings that further complicate and add risk to any attempt to buy/build flight hardware. The Project appears to have two alternatives at this time, neither of which is especially attractive.

Option 1. Systematically restructure the Project to correct known deficiencies. After the Project is restructured and deficiencies corrected, proceed to flight hardware build/procurement. This is consistent with the need to establish a sound, do-able baseline, with ECP-2 being implemented logically and completely. This option has the advantage of placing the Project on a sound footing, so that whatever commitments to delivery and cost are made can be reasonably anticipated to be achieved. The clear disadvantage is that it probably precludes being able to meet current FHA dates. Included would be efforts to complete "B" and "C" specifications, flight hardware drawings, required analyses, establish a sound CM system, etc.

Option 2. Proceed down a parallel path toward current FHA dates and cost commitments. One path would be intended to get the ECP-2 changes put in place and implemented. This is a not-insignificant task that will require focused management attention, at all levels. The output would again be a sound plan for achievement of objectives. The second of the parallel paths would be to focus near-term efforts on the completion of design and analyses on "critical path" items. Note that until the re-plan effort is completed it will not be clear exactly what items are on the critical path! The obvious advantage to this approach is that it allows productive work to proceed, while the restructuring is proceeding. The obvious disadvantage is that design and development may be proceeding down incorrect paths. Note that this approach would also require certain elements of the system to be corrected in time to support drawing releases and procurement actions, specifically the CM system should be fixed and/or certified.

Either of the above would have to be structured so that appropriate review of major elements receive attention in a forum such as a "delta" CDR on major packages prior to their release. It would be to the Project's benefit under Option 1 to conduct a full "delta CDR", with flight drawings complete, "C" specifications completed and released, analyses complete, flow-down of requirements completed and requirements traceability in place, etc.

The Board is not in position to recommend one option over the other, however two factors seem to affect the decision. First is the "zero slack" position expressed by the contractor, as well as the inability of the contractor to perform to cost/schedule plans in the past. This implies that the reality of the situation requires a deferred FHA/Launch Readiness date, because there is a high probability of not achieving anything like the current plan. Second, there are the inherent difficulties in restructuring the contract per ECP-2. Presentation material appeared to show a lack of readiness to "hit the ground running." For example, implementing an Earned Value Management (EVM) system alone will require attention from personnel who will be needed to get the design completed, etc. Whatever approach is selected, our advice would be to be realistic, so that even if the Project chooses to proceed "at risk," all are aware of what that risk is, and its consequences.

APPENDIX A – REVIEW BOARD DESIGNATION LETTER

6700 (51-02)

April 30, 2002

TO: Distribution

FROM: 6700/Microgravity Science Division

SUBJECT: Appointment of Review Board for the Critical Design Review of the Fluids and Combustion Facility Combustion Integrated Rack (51-02)

The Fluids and Combustion Facility (FCF) Combustion Integrated Rack Critical Design Review is scheduled on May 28-31, 2002 at the NASA Glenn Research Center. The Review Board for the Critical Design Review will consist of the following persons:

Chairman:	**William Taylor (Consultant)**
Safety/ Product Assurance:	Kenneth Adams (GRC)
Combustion Science:	Mun Young Choi (Drexel University)
Systems Engineering:	Daniel Gauntner (GRC)
Engineering	John Taylor (GRC)
	Tim Smith (MSFC)
Crew/Human Factors:	Janet Kavandi (JSC)
Operations/Integration:	Rickey Cissom (MSFC)
ISS Technical:	Michael Miller (JSC)
FCF Project:	Robert Corban (GRC)

This review will consist of a Critical Design Review (CDR) of the prime development of the Combustion Integrated Rack (CIR) system hardware and FCF common hardware under the Microgravity Research, Development and Operations Contract (MRDOC, NAS3-99155). In addition to a review of the detailed design of the CIR flight system hardware, a review of the CIR ground unit designs (i.e. ground integration unit, engineering development unit and training unit) and CIR flight/ground support equipment are within the scope of this CDR. The designs and engineering model test results of FCF common hardware items presented by the prime Contractor at the CDR should be assessed for their adequacy to meet the requirements of the FCF system (i.e., both the FCF Combustion Integrated Rack and the FCF Fluids Integrated Rack).

Re: 51-02
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The following areas are not within the scope of the review at the CDR.

- Detailed design review of software (a separate FCF Software Critical Design Review is planned).
- Detailed design review of some CIR diagnostics packages (review of the CIR Low Light Level Infra-Red, Low Light Level Ultra-Violet and Color Camera packages are planned by the Contractor at a later date).
- Detailed design review of the CIR Passive Rack Isolation System (PaRIS). (Due to a recent change in the vibration isolation system in CIR directed by NASA, the Contractor is required to only present CIR PaRIS performance, packaging and, as a minimum, CIR/PaRIS preliminary design at the CDR).
- Detailed review of CIR Verification and Test Readiness (a separate CIR V&TR review is planned).
- Detailed review of CIR flight safety hazards/controls (a CIR Phase II Flight Safety with the Payload Safety Review Panel was previously held).

In accordance with Critical Design Review requirements in NAS3-99155 and NASA Glenn Project Implementation Review guidelines (GRC-W6000.002), the Review Board's charter for the CDR is as follows:

- Establish that the CIR and FCF common hardware designs accommodate the science requirements. Evaluate the capabilities of the CIR to accommodate the initial payloads that are planned to fly in it (i.e., the Multi-User Droplet Combustion Apparatus, the Flow Enclosure Accommodating Novel Investigations in Combustion of Solids and the Multi-User Gaseous Fuel Apparatus).
- Establish that the CIR and FCF common hardware detailed designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved.
- Review the results of CIR and FCF common hardware engineering model system and package tests, and establish that any impacts on the flight or end item hardware specifications or designs have been addressed.
- Evaluate hardware interface compatibility between the CIR and other FCF racks, the International Space Station (ISS), Shuttle/MPLM, payload equipment to be operated in the CIR, FCF ground systems, the FCF operations control center (i.e., GRC TSC) and other interfacing items.
- Review the predicted performance of the CIR and FCF common hardware packages, including reliability.

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- Review the adequacy of the packaging of all CIR packages/subsystems and FCF common hardware items within the scope of this review.
- Evaluate CIR compliance with appropriate safety and quality requirements, and ensure that safety hazard controls have been identified.
- Evaluate the prime Contractor's fabrication/acquisition plans and readiness to construct the CIR (and FCF common hardware items).
- Evaluate the adequacy of the prime Contractor's approach and overarching plans for CIR and FCF common hardware qualification, verification and test (recognizing that detailed review of verification plans/requirements will occur at a separate V&TR review).
- Evaluate the operability of the proposed design and compliance with applicable human factors requirements. Evaluate the adequacy of the CIR ground hardware to support operations.
- Assess the prime Contractor's Project Plan, including management plan, work breakdown structure, configuration management approach, hardware/software development and test plans, schedules and costs for the prime development. Evaluate the technical, schedule and cost risks of the project.
- Evaluate past review action item responses and dispositions.

The Review Board should assess the status of the prime development of CIR and FCF common hardware in accordance with the above, and recommend whether or not the prime Contractor is ready to proceed with flight hardware fabrication, integration and test. The Board shall also identify any concerns in the prime development that should be addressed and recommend any actions that should be taken to enhance the success of the next phase of the project.

In accordance with the above guide, the Review Board shall prepare and submit a summary report of its findings within four weeks following the conclusion of the review. The report should include findings on strengths and weaknesses, recommendations by the Board and formal Requests for Action resulting from the review.

Original signed by Stephen N. Simons on 4/30/02

Stephen N. Simons
Deputy Chief, Microgravity Science Division

Re: 51-02
April 30, 2002

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6729/A. Otero
7810/D. Rohn
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APPENDIX B - ACRONYMS

Acronym	Definition
ATCU	Air Thermal Control Unit
CDR	Critical Design Review
C-IPSU	Common-Image Processing Storage Unit
CIR	Combustion Integrated Rack
CM	Configuration Management
DDT&E	Design, Development ,Test & Evaluation
DOORS	Dynamic Object Oriented Requirements System
ECP-2	Engineering Change Proposal 2
EM	Engineering Model
EPCU	Electrical Power Control Unit
EVM	Earned Value Management
FCF	Fluids and Combustion Facility
FEANICS	Flow Enclosure Accommodating Novel Investigations in Combustion of Solids
FHA	Flight Hardware Availability
FIR	Fluids Integrated Rack
GIU	Ground Interface Unit
GIU	Ground Integration Unit
GRC	NASA Glenn Research Center at Lewis Field
HFR	High Frame Rate
HiBMs	High Bit Depth/Multi-spectral
HR	High Resolution
HW	Hardware
IOP	Input/Output Processor
IPP	Image Processor Package
IPSU	Image Processing and Storage Unit
ISS	International Space Station
JSC	NASA Johnson Space Center
KSC	NASA Kennedy Space Center
MDCA	Multi-User Droplet Combustion Apparatus
MGFA	Multi-user Gaseous Fuel Apparatus,
MPLM	Multi-Purpose Logistics Module
MRDOC	Microgravity Research, Development, and Operations Contract
MSFC	NASA Marshall Space Flight Center
NGIT	Northrop Grumman Information Technology

Acronym	Definition
O_2	Oxygen
OAI	Ohio Aerospace Institute
PDR	Preliminary Design Review
PI	Principal Investigator
PRACA	Problem Reporting And Corrective Action
PS	Project Scientist
PSRP	Payload Safety Review Panel
RFA	Request For Action
RID	Review Item Discrepancy
S&MA	Safety and Mission Assurance
SDL	Serial Data Link
SEU	Single Event Upset
SRED	Science Requirements Envelope Document
TSC	Telescience Support Center
V&TR	Verification and Test Review
WBS	Work Breakdown Structure

APPENDIX C – REQUESTS FOR ACTION (RFA)

CIR-CDR-001 - Noise Emission Exceedance ATCU

Statement of Concern

Based on the rack level acoustic test of the EM hardware, NGIT is currently showing an exceedance in the rack-level NC-40 requirement levied in SSP 57000 3.12.3.3.1 at 250 Hz and 500 Hz. The requirement is not exceeded if the ATCU fan is down rated to 2000 RPMs (from 2300); however, thermal cooling is impacted unacceptably. When pressed, NGIT did not present a comprehensive plan for addressing this noncompliance. The implication of submitting a waiver at this point without further redesign, analysis, and test effort for the ATCU, both acoustically and thermally, is unacceptably risky to the CDR board.

Recommended Action

1. Study and generate thermal and acoustic design options to resolve problem.

2. Perform integrated assessment w/thermal, i.e., full trade study with thermal acoustic interaction. Employ the services of a fan noise reduction specialist to assess fan design options. After exhausting source noise options, then consider shielding options. Plan should involve experts at GRC and JSC in acoustics and thermal as study progresses.

3. Verify redesign complies with requirements. A retest of the ATCU is recommended along with a rack configuration prior to final rack acceptance test.

4. Report back to project status of effort in 3 months.

CIR-CDR-002 - Adverse effects of radiation

Statement of Concern

Although identified as a risk, it is not evident that the contractor has performed sufficient analyses or developed a risk mitigation strategy for the adverse effects of radiation on the CIR's reliability, maintainability, and availability.

Recommended Action

1. Perform a risk analysis. This analysis should identify devices and assemblies (e.g., processors, memory, and programmable logic devices) susceptible to radiation damage due to single event effects and total ionizing dosage. The analysis should include an investigation of existing failures or adverse events experienced by similar products especially those flown in high inclination orbits which pass through the South Atlantic Anomaly (SAA).

2. Develop a risk mitigation strategy. This strategy should include options such as radiation testing of critical devices/assemblies, use of hardware and/or software Error Detection and Correction (EDAC), multiple buffering and comparison of commands and data before execution, arm/fire sequencing, and sparing strategy.

CIR-CDR-003 - Maintainability Analysis Report and Operational Availability

Statement of Concern

Contractor has not reported if CIR meets is Operational Availability Requirement. If a Mitigation Plan is needed, it has not been developed. (Ref. RISK 115)

Recommended Action

The Contractor shall complete the Maintainability Analysis and Operational Availability Analysis for the Combustion Integrated Rack (CIR). These analyses shall be documented and delivered to NASA as soon as possible after the CIR CDR. (Ref. Contractor Analysis Report No. CIR-ANA-1260).
The Contractor shall report within CIR-ANA-1260 the following information:
(1) The Availability Model (Block Diagram) and explanation of methodology for availability analysis. (2) All special assumptions and ground rules for the availability analysis. (3) All input data sources for relevant input parameters such as MTBF, MTTR, MADT, and MLDT. (4) Results of sparing analysis and proposed sparing plan. (5) Results of the qualitative maintainability analysis of the CIR design and discussion of provisions for corrective maintenance. (6) Preventative maintenance plan for hardware devices with limited life. (7) Sensitivity analysis to show the components that have the highest potential to increase CIR operational availability by increasing inherent reliability or sparing provisions (8) In the event that the CIR does not meet its availability allocation target to support an overall FCF availability requirement of 0.83, CIR-ANA-1260 shall indicate this result and shall propose a recovery plan to achieve the availability allocation target. In addition, since the CIR Allocation Analysis was not reported in the Reliability Summary Report, CIR-ANA-1260 shall contain the results of the CIR Allocation Analysis.

CIR-CDR-004 - Problem Review Board

Statement of Concern

While the CIR contractors have a problem reporting system and an electronic PRACA database, there does not appear to be any formal system in place to review problems and ensure they are resolved.

Recommended Action

Establish a Problem Review Board (PRB) or other formal process to track all problem reports (i.e., PRACAs) and ensure they are properly addressed in a timely manner. Structure the PRB to facilitate identification of problem trends, to enhance communication among contractors and to ensure all projects benefit from lessons learned. Include government participation on PRB or coordinate with an independent government PRB.

CIR-CDR-005 - Integrated Diagnostics Testing

Statement of Concern

At this time, the Contractor has no plans to perform an integrated test of the system on the ground using a real or simulated experiment in the combustion chamber. The diagnostic packages, image processing packages, and optical components (including chamber windows and fiber optic interconnects) need to be demonstrated in an integrated test to validate overall system performance.

Recommended Action

Develop a test scenario and associated test plan to demonstrate and validate the end-to-end diagnostics system (camera to disk) in the rack using a real or simulated experiment in the chamber. This test shall be performed after all engineering model packages have been assembled and tested individually.

CIR-CDR-006 - Traceability of PDR RIDs

Statement of Concern

There was no traceability of PDR RIDs provided at the CDR. It was stated that the contractor was not required by contract do so, and therefore it had not been done, even though it was known how many had been incorporated.

Recommended Action

The Project should attempt to reconstruct the incorporation trail and ensure that important issues are not lost.

CIR-CDR-007 – Complete Specifications

Statement of Concern

The “B” Spec is incomplete, and requirements are not completely “flowed down”. As a controlling specification, the CIR B-spec is absolutely necessary to define and control the CIR design.

Recommended Action

Working with NASA, complete the CIR B-spec. This includes resolving all issues through a formal process with increase attention on future payloads beyond MDCA. Update the compliance statements along with indications of Comply or if no testing has been performed, indicate when testing will be completed.

CIR-CDR-008 – FCF/CIR Exceptions

Statement of Concern

There was no cohesive plan shown at the CDR Review which establishes how and when the listed exceptions will be submitted to ISS/JSC, and when action is required for closure. Some exceptions require immediate action, while others can reasonably wait, and attention should be focused on the most important ones.

Recommended Action

A plan (who, what, when, etc.) shall be developed for the closure of all identified FCF/CIR Exceptions. All waivers shall be identified and included in this plan. The closure of the exceptions/waivers shall be worked with the ISS Program as soon as possible. Any exceptions that have potential for not been approved shall be identified and given higher priority.

CIR-CDR-009 - On-orbit Stowage

Statement of Concern

The CIR plans to have a significant amount of on-orbit stowage. Both up-mass and volume, and on-orbit stowage space are critical elements for any payload, and it is the FCF/CIR Project's responsibility to stay within available limitations.

Recommended Action

Perform an analysis of the stowage volume required for all CIR spares, installation hardware, maintenance items, payload equipment, etc. Determine the minimum set of on-orbit hardware required with associated stowage requirements. Work with the ISS program to determine a proper phasing of these items and determine a realistic scenario for their deployment. Incorporate stowage limitations into the availability of the FCF.

CIR-CDR-010 - Qualification Approach

Statement of Concern

The qualification plan for CIR and common hardware was not explicitly defined at the CDR review. This must be clearly established and reviewed by all concerned, since it establishes critical performance capability.

Recommended Action

The qualification approach for each item of flight hardware needs to be explicitly defined. Criteria shall be established to determine for requalification due to design modifications from requirement changes, testing results/failures, etc. Packages only going through protoflight testing shall be clearly identified with associated risks.

CIR-CDR-011 - Configuration Management and Control

Statement of Concern

Evidence at the CDR Review, including numerous RIDs, indicates that the contractor's implementation of required CM practices is deficient. Should deficiencies exist, they could seriously weaken the required integrity of flight hardware and software.

Recommended Action

Assurances shall be made that the Configuration Management system and its associated processes are properly in place, being utilized by the FCF team properly, adequate resources, and trained personnel. This shall include an audit by NASA of the CM systems. Any identified weaknesses shall be corrected as soon as possible.

CIR-CDR-012 - Vendor and Manufacturing Sources

Statement of Concern

Long lead times have been identified, but the lead-time provided seems to be a variable. Times are different in three different areas (presentation, handout, and integration plan), which indicates that the times are not well established with the vendors.

Recommended Action

The contractor shall obtain commitments from its vendors and manufacturing sources for delivery of parts and services. NASA shall assist the contractor in obtaining assurance from the vendors to meeting delivery dates. The vendors shall be monitored to assure commitments are being honored.

CIR-CDR-013 - Identified Risks

Statement of Concern

The Risk Management System did not appear to account for many risks associated with approval of ECP-2, and risk items identified at the CDR Review. As a properly functioning management tool, the Risk Management process must include all appropriate risks, with risk mitigation strategies identified and tracked.

Recommended Action

The contractor and NASA shall update the project risks to clearly identify the new “challenges” based on ECP-2. An appropriate mitigation plan for each risk shall be developed and tracked.

CIR-CDR-014 - Tracking and Closure of RIDs

Statement of Concern

RIDs from prior FCF reviews were not tracked to assure appropriate closure. RIDs are normally considered “Quality Records”, and must have an appropriate tracking and closure process.

Recommended Action

All RIDS identified at this CDR review (see CDR RIDs, Attachment 1) and subsequent reviews shall be documented, tracked, and closed in an appropriate manner. Feedback shall be provided to the initiator to assure disposition was appropriate.

APPENDIX D – REVIEW ITEM DISCREPANCIES (RIDS)

Please refer to Attachment 1 (Microsoft Excel Spreadsheet) for a compiled list of Review Item Discrepancies submitted for the CIR Critical Design Review.